Design of Demand Response Pricing Mechanism Under the Trend of Sustainable Development: The Case of Gansu

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Abstract. In Gansu Province, China, the power supply is more than demand, and the imbalance between power supply and demand needs to be solved urgently. As an important means of DSM, demand response can effectively alleviate the peak valley difference and reduce the power supply cost. This paper first summarized the development status of demand response in Gansu Province, and then proposed a demand response pricing mechanism to adapt to different stages of power market reform in Gansu Province.

Keywords: demand response · pricing mechanism · sustainable development

1 Introduction

Electric power is the basic industry of national economy, the fluctuation of electricity price is related to the overall situation of national economic and social development. In recent years, installed power capacity in China has been in a state of excess capacity, renewable energy abandon phenomenon also happens [1, 2]. Especially after the "30.60" carbon neutralization target is put forward, green energy will be further developed and it poses new challenges to the stable operation of power grid. Demand response can be used as a long-term effective method to deal with the increasingly complex power demand [3], so as to minimize the transmission and distribution costs of power grid companies. Demand response means that when the price of wholesale electricity market rises or the reliability of power system is threatened, after receiving the direct compensation notice of leading load reduction or the signal of rising electricity price from the power supplier, the power users change their inherent habitual electricity consumption mode to reduce or transfer the electricity load in a certain period and respond to the power supply [4]. Demand response can ensure the stability of power grid, which is a short-term behavior to restrain the rise of electricity price [5]. Therefore, a reasonable electricity price mechanism is conducive to better guide users to adjust their power consumption behavior, form a model suitable for power generation load and power consumption load, and is conducive to the safe and economic operation of power grid. For example,

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literature [6] proposed a differentiated peak price mechanism to guide air conditioning load to participate in demand response. This paper summarized the development status of demand response in Gansu Province, and then proposed a demand response pricing mechanism to adapt to different stages of power market reform in Gansu Province.

2 Current Situation of Demand Response Construction in Gansu Province

Gansu's demand response is mainly in the form of participating in ancillary services. Gansu province implements peak valley electricity price. According to the power consumption of large users in the grid, silicon carbide, ferroalloy and cement users avoid peak production during peak electricity price period. At the same time, the overall power consumption of Gansu Province is insufficient. The total installed capacity of grid connected power generation of Gansu Power Grid is 52.86 GW. Figure 1 shows the power generation load curve of Gansu Province on August 31, 2020. The maximum power generation load on that day is 20.77 GW, which is only 39.3% of the total installed capacity of power generation. It can be seen that the power industry in Gansu Province is characterized by oversupply. Therefore, the demand response goal of Gansu Province is to encourage users to use electricity, and to increase the power load timely and accurately when the new energy consumption is difficult and the peak shaving capacity of the generation side is insufficient, so as to expand the new energy consumption space. Through the price guide users to use more electricity, not only can achieve the purpose of promoting new energy consumption, but also can reduce the cost of electricity, forming a virtuous circle of multiple benefits.

Based on the principle of "voluntary declaration and fair bidding", Gansu Power Grid demand side resource auxiliary service market officially put into trial operation. The demand side resource ancillary service market is of great significance to expand the power market, regulate power grid resources, realize the safe and stable operation of power grid, promote new energy consumption, and improve the level of lean dispatching.

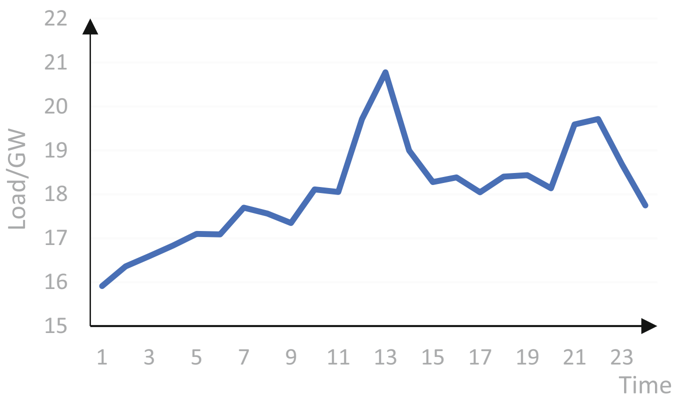

Fig. 1. Power generation load curve of Gansu Province on August 31, 2020

Although there are only individual enterprises in Lanzhou, Wuwei, Zhangye and other cities participating in Gansu power demand side auxiliary service market, it has sent a signal to the power users of the whole province that Gansu Power market-oriented reform is constantly advancing, and finally it is necessary to transition from the unilateral spot market on the generation side to the bilateral market with wide participation of users.

3 Design of Gansu Demand Side Response Pricing Mechanism Under Electricity Marketization

This section designs incentive based response and price based response pricing mechanisms respectively.

3.1 Design of Incentive Based Demand Response Pricing Mechanism

The compensation mechanism of Gansu Province is jointly operated by the "visible hand" of the government and the "invisible hand" of the market. The government sets the upper limit of compensation fees, and then the final compensation price is determined by the way of market bidding. Next, the incentive demand response pricing mechanism of Gansu Province is designed from four aspects: the participants, the source of funds, the upper limit of compensation fee declaration and the allocation mechanism.

(1) Participants of Demand Response

With the further deepening of power market reform, the participants of demand response should be further expanded. Users with AGC function and installed charging power of 10 MW or less, continuous charging time of 4 h or less can also participate in auxiliary services through unified dispatching of electric energy storage resource agents. In addition, there is no regulation on the participation of electric vehicles in the demand side ancillary services market. When the infrastructure construction such as charging pile is improved and V2G technology is more mature in the future, electric vehicles will have great peak shaving potential. Therefore, electric vehicles can be included in the scope of demand response resources. Electric vehicles with V2G technology and continuous charging time of more than 4 h can participate in the demand side peak shaving auxiliary service market through load agents.

(2) Sources of Demand Response Compensation Funds

Referring to the existing auxiliary service market rules and the actual situation of supply and demand in Gansu Province, according to the principle of "who benefits, who bears", the demand response compensation fund should be shared by all kinds of power plants (including new energy power plants) and power users, and should be borne by users through the collection of auxiliary service fees in the future. Therefore, a demand response fund pool can be established to make up for the demand response cost. The sources of funds mainly include the following two parts:

1) Part of the payment based on the proportion of monthly real-time deep peak shaving of the power plant. The current "rules" stipulate that the compensation cost of users participating in power grid peak shaving shall be apportioned and paid according to the monthly compensation proportion of each power plant. Therefore, each power

plant needs to provide monthly compensation for real-time deep peak shaving service in proportion to the demand response fund pool.

2) Auxiliary service fees paid by users. Demand response improves the quality, reliability and safety of power consumption. Therefore, the cost of user's participation in demand response needs to be shared by users, and this part of the cost can be included in the form of auxiliary service cost and transmitted to users.

(3) Upper Limit of Demand Response Compensation Expense Declaration

At present, the upper limit of compensation for demand side resources participating in peak shaving auxiliary services in Gansu Province is 0.2 yuan/kWh. According to the historical demand response cases, most users participate in the response during the current peak hours. In order to arouse the enthusiasm of users, the upper limit of compensation fee should be raised to make it higher than the price difference between peak period and average period which is between 0.17 and 0.22 yuan/kWh, so the upper limit of compensation can be temporarily adjusted to 0.3 yuan/kWh. With the gradual improvement of power market construction, the upper limit of compensation can be gradually released, and the compensation cost can be determined by market bidding.

(4) Cost Sharing Mechanism of Demand Response Compensation

According to the principle of auxiliary service responsibility and "who benefits who pays", power plants and power users share the demand response cost. The apportionment amounts of the generation side and the user side are shown in formula (1) and (2) respectively:

$$F_G = \frac{a}{a+b} \times C_{fee} \tag{1}$$

$$F_C = \frac{b}{a+b} \times C_{fee} \tag{2}$$

In the formula, F_G represents the total apportionment amount undertaken by the generation side; a is the cost sharing ratio of demand response on generation side; b represents the demand response cost sharing ratio of the power user side; C_{fee} is the total demand response cost; F_C represents the total apportionment amount borne by the user side.

In the early stage of power market reform, the power users' acceptance of peak shaving auxiliary service sharing fee is not high, so the user's sharing coefficient b can be appropriately reduced, that is, the sharing is mainly based on the peak shaving responsibility on the generation side. With the maturity of the market and the improvement of the relevant mechanism, b can be gradually increased. In the end, according to the principle of responsibility and "who benefits, who bears", the peak shaving cost will be mainly paid by the power users.

3.2 Design of Price Based Demand Response Pricing Mechanism

The price based demand response in Gansu Province is mainly manifested in the peak valley TOU price mechanism. According to the market environment and reform stage, we should constantly adjust the peak valley time of use pricing mechanism, so as to better guide users to use electricity reasonably and improve the power market. The following is the design of pricing mechanism in different stages of market-oriented reform.

(1) Mechanism Design of Peak Valley Electricity Price Period and Level in the Early Stage of Market Reform

In order to facilitate users to better understand and accept the electricity price and better link up the current peak valley electricity price mechanism, after the peak valley period is determined according to the net load clustering and scenario analysis method, the relatively simple and easy to understand methods, such as the up-down floating proportion method and the peak valley method, can be used to establish the model and formulate the peak valley electricity price. Up-down floating proportion method is a common method to determine peak valley price. It is based on the average price of electricity, floating up and down a certain proportion to get the peak price or low price. The calculation formula is as follows:

$$P_f = P_p \times (1 + k_f) \tag{3}$$

$$P_g = P_p \times (1 + k_g) \tag{4}$$

In the formula, P_f is the peak electricity price, P_p is the flat section electricity price, P_g is the valley electricity price, k_f is the proportion of the peak electricity price floating up, k_g is the proportion of the valley electricity price floating down.

The peak valley method is used to determine the valley price based on the average section, and then the peak price is determined according to the relationship among valley section, average section and peak section. The calculation formula is as follows:

$$P_f = \frac{R - (P_p \times Q_p + P_g \times Q_g)}{Q_f} \tag{5}$$

In the formula, R is the income of the power grid without peak valley price or the income before peak valley price adjustment, Q_f is the peak electricity, Q_P is the average electricity, and Q_g is the low electricity.

(2) Design of Peak Valley Electricity Price Adjustment Mechanism in the Early Stage of Marketization

In order to further promote the market-oriented reform and give full play to the commodity attribute of electricity, we should adopt the pricing mechanism of generation, transmission and distribution linkage, so that the time-sharing cost of power transmission and distribution on the supply side can be transmitted to the sales price on the demand side in time.

The peak valley electricity price adjustment mechanism of generation transmission distribution sales linkage means that electricity, as a general commodity, sales link as the final link, should fully reflect the change of time-sharing cost of generation transmission distribution link. When the time-sharing cost of power generation, transmission and distribution changes more than a certain proportion x, it is necessary to timely adjust the peak valley time-of-use price of sales instead of fixed time. The ratio x is the ratio coefficient that touches the adjustment of peak valley electricity price, which can be determined based on the balance of market main body's interests, user's affordability and social stability.

(3) Mechanism Design of Peak Valley Electricity Price in Mature Period of Market Reform

After the electricity trading market is mature, the electricity commodity attribute is restored. Spot market real-time electricity price is the main supply and demand signal of electricity market. The peak valley price of the user side should establish a linkage mechanism with the spot market real-time price to guide users to use electricity reasonably. The fixed peak valley price package considering risk and exponential peak valley price package mechanism linked with spot market and transmission and distribution cost can be established to give users more options to consider the risk of power market. The two pricing mechanisms can be expressed by formula (6) and formula (7):

$$P_1' = P_1 \times (1 + \varepsilon_1) \tag{6}$$

$$P_2' = P_2 \times (1 + \varepsilon_2) \tag{7}$$

In the formula, P_1' is the fixed peak valley price level considering risk factors; P_1 is the selling cost of electricity price; ε_1 is the risk index; P_2' is the exponential peak valley price level considering the linkage with spot market and transmission and distribution cost; P_2 is the original peak valley electricity price level; ε_2 is the cost fluctuation index of the grid side and the transmission and distribution side.

4 Conclusion

Firstly, this paper analyzes the current situation of demand response construction in Gansu Province of China, and then designs incentive and price based demand response pricing mechanisms respectively. At first, the incentive demand response pricing mechanism of Gansu Province is designed from the aspects of participants, sources of funds, upper limit of compensation fee declaration, and allocation mechanism. It is suggested that in the future, electric energy storage resources with AGC function and V2G technology, with charging power of 10 MW or less and lasting charging time of 4 H or less should be further considered. In order to further improve the enthusiasm of users to participate in demand response, it is suggested to increase the compensation standard of demand response and gradually transition to market bidding pricing. Then, the pricing mechanism of peak valley price is designed by stages. In the initial stage, the floating proportion method and the valley (peak) method are implemented, and the peak valley price is adjusted by the pricing mechanism of transmission and distribution linkage. In the mature stage, the mechanism of linkage with spot market real-time price is adopted.

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